610
Highway Capacity

610.01 GENERAL

The term "capacity" is used to express the maximum number of vehicles that have a reasonable expectation of passing over a section of a lane or a roadway during a given time period under prevailing roadway and traffic conditions. Highway capacity is of vital concern in the design of highways. A knowledge of highway capacity is essential to the proper fitting of a planned highway to the requirements of traffic. It helps both in the selection of highway type and in determining dimensional needs such as number of lanes.

The purpose of this section is to provide the user with enough information to perform a preliminary capacity analysis for basic highway sections. This chapter also gives a basis for determining the need for more detailed capacity analysis.

This *Design Manual* chapter does not cover preliminary capacity analysis for highway portions with signal spacing of less than 2 miles and those within 2,500 feet of interchange ramps.

610.02 DEFINITIONS AND SYMBOLS

(1) Definitions

Average Daily Traffic (ADT). The volume of traffic passing a point or segment of a highway, in both directions, during a period of time, divided by the number of days in the period and factored to represent an estimate of traffic volume for an average day of the year.

Directional Design Hour Volume (DDHV). The traffic volume for the peak hour in the peak direction of flow; usually a forecast of the relevant peak hour volume. (Units of DDHV are vehicles per hour. DDHV should be rounded to the nearest 50 vph.)

Freeway. A divided highway facility that has a minimum of two lanes for the exclusive use of traffic in each direction and full control of access.

Level of Service (LOS). A qualitative measure describing the operational conditions within a traffic stream; generally described in terms of such factors as speed, travel time, freedom to maneuver, comfort and convenience, safety, and others. See Figure 610-1 for appropriate design levels of service for different highway types.

Multilane Highway. A highway with at least two lanes for the exclusive use of traffic in each direction, with or without partial control of access, that may have periodic interruptions to flow at signalized intersections.

Peak Hour Factor (PHF). The ratio of the volume occurring during the peak hour to the maximum rate of flow during a given time period within the peak hour. It is the measure of peaking characteristics of a highway section or intersection.

Service Flow Rate (SFL). The maximum hourly rate of flow that can be accommodated past a point or short uniform segment of traffic lane (for multilane) or the entire roadway (for a two-lane facility), under prevailing traffic, roadway, and control conditions while maintaining a stated level of service; value is specific to a given level of service.

Terrain.

(a) **Level Terrain.** Any combination of grades and horizontal and vertical alignment permitting heavy vehicles to maintain approximately the same speed as passenger cars; this generally includes short grades of no more than 1 to 2 percent.

(b) **Rolling Terrain.** Any combination of grades and horizontal or vertical alignment causing heavy vehicles to reduce their speeds substantially below those of passenger cars, but not causing heavy vehicles to operate at crawl speeds for any significant length of time.

(c) **Mountainous Terrain.** Any combination of grades and horizontal and vertical alignment causing heavy vehicles to operate at crawl speeds for significant distances or at frequent intervals.

Heavy vehicle is defined as any vehicle having more than four tires touching the pavement. Crawl speed is the maximum sustained speed which heavy vehicles can maintain on an extended upgrade of a given percent.

(2) Symbols

K	The percentage of ADT occurring in the peak hour.
D	The percentage of peak hour traffic in the heaviest direction of flow.
KD	The product of K and D.
f_E	Adjustment factor to account for the effect of the highway's access and egress points (intersections, driveways, ramps) and whether or not it is a divided highway. (See Figure 610-2.)

610.03 DESIGN

(1) Design Responsibility

District Location Project Engineer's office initiates the process of highway capacity determination and performs the capacity analysis for the highway segment under consideration. If the capacity analysis goes beyond the scope of this chapter, the district Traffic Design Office or the Travel Data Office of the headquarters Planning, Research and Public Transportation Division should be requested to do the analysis. This request should be made as soon as possible to ensure that the capacity analysis is completed during the design report stage.

(2) Two-Lane Rural Highway

The objective of capacity analysis for two-lane rural highways is to determine the design level of service for a given segment for future sets of conditions.

- Determine the appropriate design level of service from Figure 610-1.
- Select the appropriate maximum allowable ADT directly from Figure 610-3 for the highway's level of service, K factor (percent of ADT occurring in peak traffic) and terrain type. No computations are needed at this stage.
- Compare the maximum allowable ADT to the expected ADT at design year. If the maximum allowable ADT is less than the design year ADT, a more detailed capacity analysis is warranted.

(3) Multi-Lane Highway

- Determine the DDHV, given the anticipated ADT during the deisgn year, using the formula:

  DDHV = ADT x KD where

  KD = 0.11 for rural
  0.08 for suburban
  0.05 for urban

  Use these general values when specific values for the particular corridor are unavailable. Generally, multi-lane highways with less than ten uncontrolled access points(driveways, intersections, ramps) per mile (on one side) are considered to be "rural" while those with more than ten uncontrolled access points per mile are considered to be suburban.
- Select an appropriate value of the service flow rate per lane (SFL) from Figure 610-4 for the highway's level of service (from Figure 610-1), environment type (urban, suburban, or rural) and terrain type.
- Determine the required number of lanes in each direction, N, from the formula:

  $N = DDHV/(SFL \times f_E \times PHF)$

  where f_E is found in Figure 610-2 and PHF in Figure 610-5. Round the value, "N", to the nearest whole number.
- Compare 2N to the number of lanes proposed. The proposed number of lanes should be greater than or equal to 2N. Otherwise, a more detailed capacity analysis is warranted.

(4) Basic Freeway Sections

- Determine the DDHV, given the anticipated ADT during the design year, using the formula:

  DDHV = ADT x KD where

  KD = 0.11 for rural freeways
  0.07 for suburban freeways
  0.05 for urban freeways

  Use these values when specific values for the particular corridor are unavailable.
- Select an appropriate value of the service flow rate per lane, SFL, from Figure 610-6 for the prevailing truck percentage and terrain and for the required LOS (from Figure 610-1).
- Determine the required number of lanes in one direction, N, from the formula:

  $N = DDHV/(SFL \times PHF)$

  where PHF can be obtained from Figure 610-5. Round the value, "N", to the nearest whole number.
- Compare 2N to the number of lanes proposed. The proposed number of lanes should be greater than or equal to 2N. Otherwise, a more detailed capacity analysis is warranted.

(5) Miscellaneous Highway Sections

For the capacity analysis of intersections, highways with signal spacing of 2 miles or less, highways within 2,500 feet of interchange ramps, ramps, weaving sections, transit systems, and bicycle and pedestrian trails, refer to the *Highway Capacity Manual* (Special Report No. 209, Washington, D.C.: Highway Research Board, 1985). Refer to Chapter 910 for channelization guidelines. The district Traffic Design Office or the Travel Data Office of the Headquarters Planning, Research and Public Transportation Division should be requested to do the capacity analysis on these miscellaneous highway sections.

Highway Type[2]	Rural[1] Level	Rural[1] Rolling	Rural[1] Mountainous	Urban and[1] Suburban
Principal Arterial	B	B	B	C
Minor Arterial	B	B	C	C
Collector	C	C	D	D
Local Access	D	D	D	D

NOTES:

(1) Refer to 610.02 and Chapter 440 for definitions of these area types..

(2) Refer to Chapters 120 & 440 for definitions of these highway types.

TYPE OF AREA AND APPROPRIATE LEVEL OF SERVICE

Figure 610-1

	No Access Control		Partial Access Control	
Type	Divided	Undivided	Divided	Undivided
Rural	1.00	0.95	1.00	0.95
Suburban	0.90	0.80	1.00	0.95

ADJUSTMENT FACTOR FOR TYPE OF MULTILANE HIGHWAY AND DEVELOPMENT ENVIRONMENT, f_E

Figure 610-2

K-FACTOR	LEVEL OF SERVICE				
	A	B	C	D	E
	Level Terrain[2]				
0.10	2,400	4,800	7,900	13,500	22,900
0.11	2,200	4,400	7,200	12,200	20,800
0.12	2,000	4,000	6,600	11,200	19,000
0.13	1,900	3,700	6,100	10,400	17,600
0.14	1,700	3,400	5,700	9,600	16,300
0.15[5]	1,600[5]	3,200[5]	5,300[5]	9,000[5]	15,200[5]
	Rolling Terrain[3]				
0.10	1,100	2,800	5,200	8,000	14,800
0.11	1,000	2,500	4,700	7,200	13,500
0.12	900	2,300	4,400	6,600	12,300
0.13	900	2,100	4,000	6,100	11,400
0.14	800	2,000	3,700	5,700	10,600
0.15[5]	700[5]	1,800[5]	3,500[5]	5,300[5]	9,900[5]
	Mountainous Terrain[4]				
0.10	500	1,300	2,400	3,700	8,100
0.11	400	1,200	2,200	3,400	7,300
0.12	400	1,100	2,000	3,100	6,700
0.13	400	1,000	1,800	2,900	6,200
0.14	300	900	1,700	2,700	5,800
0.15[5]	300[5]	900[5]	1,600[5]	2,500[5]	5,400[5]

NOTES:

(1) Assumed conditions include 60/40 directional split, 14 percent trucks, 4 percent RV's and no buses.

(2) 20 percent, no passing zones.

(3) 40 percent, no passing zones.

(4) 60 percent, no passing zones.

(5) Use for rural two-lane highways, when k-factor is unavailable.

MAXIMUM ADT VS. LEVEL OF SERVICE AND TYPE OF TERRAIN FOR TWO-LANE RURAL HIGHWAYS[1]

Figure 610-3

LEVEL OF SERVICE	PERCENT TRUCKS[2]				
	0	5	10	15	20
	Level Terrain				
A	700	700	650	650	600
B	1,100	1,050	1,000	1,000	1,000
C	1,400	1,350	1,300	1,250	1,250
D	1,750	1,700	1,650	1,600	1,550
E	2,000	1,950	1,850	1,800	1,750
	Rolling Terrain				
A	700	600	550	500	500
B	1,100	950	850	800	700
C	1,400	1,200	1,100	1,000	900
D	1,750	1,500	1,350	1,250	1,100
E	2,000	1,750	1,550	1,450	1,250
	Mountainous Terrain				
A	700	500	400	350	300
B	1,100	800	650	550	450
C	1,400	1,050	850	700	600
D	1,750	1,300	1,050	850	750
E	2,000	1,500	1,200	1,000	850

NOTES:

(1) Service flow rates are in units of vehicles per hour per lane (vphpl).

(2) Truck percentages should include both the single units (two and three axle trucks and buses) and the combinations (trucks with trailers and trailer combinations).

SERVICE FLOW RATE PER LANE (SFL)[1] FOR MULTILANE HIGHWAYS

Figure 610-4

Metropolitan Area Population	Peak-Hour Factor
Over 1,000,000	0.91
500,000 - 1,000,000	0.83
Under 500,000	0.77

PEAK-HOUR FACTORS

Figure 610-5

LEVEL OF SERVICE	PERCENT TRUCKS[2]				
	0	5	10	15	20
	Level Terrain				
A	700	650	650	600	600
B	1,100	1,050	1,000	950	950
C	1,550	1,500	1,450	1,350	1,300
D	1,850	1,800	1,700	1,600	1,550
E	2,000	1,900	1,850	1,750	1,700
	Rolling Terrain				
A	700	600	550	500	450
B	1,100	950	850	750	700
C	1,550	1,350	1,200	1,050	1,000
D	1,850	1,600	1,400	1,300	1,150
E	2,000	1,750	1,550	1,400	1,250
	Mountainous Terrain				
A	700	500	400	350	230
B	1,100	800	650	550	400
C	1,550	1,150	900	750	550
D	1,850	1,350	1,100	900	650
E	2,000	1,500	1,200	1,000	700

NOTES:

(1) Service flow rates are in units of vehicles per hour per lane (vphpl).

(2) Truck percentage should include both the single units (two and three axle trucks and buses) and the combinations (trucks with trailers and trailer combinations).

SERVICE FLOW RATES PER LANE (SFL) FOR FREEWAYS[1]

Figure 610-6